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TELEMETRY TEST SYSTEM

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by
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INTRODUCTION

The expanding requests for satellite data from the "STADAN" network and the continuous addition of more varied and complex telemetry equipment to perform the assigned tasks have greatly increased the problem of system reliability. In particular, the need for rapid checkout techniques to insure the functional operability of the "STADAN" telemetry system at any given time has presented itself. The Telemetry Test System described herein represents one effort to meet this challenge.

The overall function of this device is to generate a digital data train, transmit this data through various data handling systems under test, receive the data transmitted, and make a bit-by-bit analysis to determine any errors caused by the equipment under study. These errors can usually be attributed to two factors; either the noise present on the data is of such magnitude that the equipment under evaluation cannot distinguish between a binary "1" or binary "0", or there is a malfunctioning unit within the system being tested. The differentiation between these two possibilities can be readily observed and overall performance determined.

A prototype of the Telemetry Test System has been designed and built and a technical discussion of the unit is given in this memorandum.

BLOCK DIAGRAM ANALYSIS OF THE TELEMETRY SYSTEM

The Telemetry Test System consists of four subsystems each of which is designed to operate under two general modes, "Ring" or "Pseudo-Random". These four subsystems and modes of operations are considered in detail. Refer to Block Diagram #1 for representation of the subsystems and their function in the Telemetry Test System.

Generator Subsystem: Pseudo-Random Mode

The first subsystem to be considered is a maximal length sequence generator consisting of a shift register and an "Exclusive OR" circuit. This unit will provide a digital pulse train of all the possible combinations of "1" and "0" available from the shift register length selected, excluding an all "0" condition. This method of digital generation is called the "Pseudo-Random" mode.

The first feedback selection Q_o determines the length of the register "n", and is fed to one side of the "Exclusive OR" circuit. The second feedback selection Q_i determines the proper input to the other side of the "Exclusive OR" circuit, the output of which is fed back to the first stage of the register, giving $2^n - 1$ possible combinations.

Strobes are generated within this subsystem from a clock pulse train for sampling the "Exclusive OR" and shifting its output into the shift register. The output of the "Exclusive OR" is simultaneously fed to the "Format Generator" within the subsystem, and these strobe pulses are utilized to convert the "Exclusive OR" output to one of three telemetry codes, NRZ-Change, NRZ-Mark, or Bi-Phase.

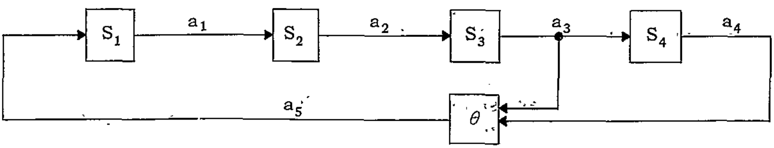
The telemetry generator design permits a maximum length of 20 bits and can generate a pseudo-random sequence of up to 1,048,575 bits.

The mathematical description of utilizing the "Exclusive OR" circuit and shift register to formulate these pseudo-random patterns is discussed in the following paragraphs.

Any linear recurring sequence can be generated by a recursion formula in which the M digit is a function of the preceding i digits, i.e.,

$$A_m = \phi\left(A_{m-1}, A_{m-2} \cdots A_{m-i}\right)$$

In the case of a binary shift register the recursion formula is relatively simple, ϕ (a) being the modulo 2 sum of some of the preceding i digits. For a maximum length sequence ϕ (a) must be chosen such that the period $P = 2^m - 1$ where m is the length of the register. For example, a four-stage register will give rise to a sequence of length 15 if $a_5 = a_4 \oplus a_3$. This sequence can be implemented as shown below:



and gives rise to the sequence 111100010011010. The successive states of the register and the decimal equivalent of binary representation of these states are as follows:

t_0	1	1	1	1	15
t_1	0	1	1	1	7
t_2	0	0	1	1	3
t_3	0	0	0	1	1
t_4	1	0	0	0	8
t_5	0	1	0	0	4
t_6	0	0	1	0	2
t_7	1	0	0	1	9
t_8	1	1	0	0	12
t_9	0	1	1	0	6
t_{10}	1	0	1	1	11
t_{11}	0	1	0	1	5
t_{12}	1	0	1	0	10
t_{13}	1	1	0	1	13
t_{14}	1	1	1	0	14
t_{15}	1	1	1	1	15

It should be noted that the recursion formula precludes an all-zero state which results in the period being $P = 2^n - 1$. This is a necessary condition in generating binary linear sequences for if the register reached an all-zero state it would remain in that condition ad-infinitum.

Generator Subsystem: Ring Mode

The "Ring" mode of operation is generated by a Binary Selector Switch which sets into the register a pre-determined pattern. The output of the shift register is then fed directly to the input of the shift register and a redundant binary train is generated. The output of the shift register is simultaneously fed to the Format Generator for a selected code output. The "Exclusive OR" circuit is not utilized in this mode of operation.

The outputs from the Format Generator for "Pseudo and Ring" modes of operation are transmitted to the various systems under test.

<u>Telemetry Receiver Subsystem: Pseudo-Random Mode</u>

In the "Pseudo-Random" mode, the purpose of the receiver is to first synchronize itself with the data from the Generator, and then independently produce a pattern identical to the one received from the Generator.

This subsystem consists of a 20 bit shift register and an "Exclusive OR" circuit, identical to the one used in the Generator.

For "Pseudo-Random" operation, the data received from the Generator is transmitted through the system under test and through a bit synchronizer which provides a clock in synchronization with the input data rate for the receiver strobe generator. The data from the bit synchronizer is fed into the input of the receiver shift register. As this data is transferred into the shift register, an "Exclusive OR" circuit compares the two feedback points (Q_i and Q_o) which have been selected to correspond with the identical feedback points in the generator subsystem. The output of this "Exclusive OR" circuit is fed to another "Exclusive OR" unit. The other input to this "Exclusive OR" unit is data from the bit synchronizer.

If the Receiving shift register has a non-identical binary configuration from that of the Generator, the maximum number of bits necessary for synchronization is the length of the shift register selected. This is assuming that no errors are generated by the equipment under test. In the presence of errors, more bits are required. When synchronization occurs, the "Exclusive OR" circuit will output a pattern identical to that of the Generator and the second "Exclusive OR" unit will indicate that synchronization has been obtained.

<u>Telemetry Receiver Subsystem: Ring Mode</u>

In the "Ring Mode", the purpose of the Receiver is to act as a delay mechanism so that the direct output of the Generator can be compared with the data from the system under test.

The continuous pattern of the "Generator" is fed directly to the input of the "Receiver" shift register. By utilizing the feedback selector (Q_i) a delay of one bit equal to the length of the shift register selected can be introduced. The other input (Q_0) of the "Exclusive OR" circuit will be switched to the data from the system under test. By utilizing a strobe delay circuit generator which produces strobe pulses in 1/8 bit increments, a bit-by-bit comparison is made of the

incoming data. The strobe delay generator circuit can also be used in the "Pseudo-Random" mode if the Signal Conditioner and Bit Synchronizer is not being utilized.

The output of the "Exclusive OR" circuit is fed to the "Up-Down" subsystem. The second "Exclusive OR" unit is not utilized in the "RING" mode of operation.

Up-Down or Up-Counter Subsystem

This subsystem is essentially a five-stage BCD counter with Nixie displays to indicate static conditions. The function of the BCD counter is two-fold. First it is utilized in the synchronization process, and it is then used to count and display errors.

In the "Up-Down" condition, this subsystem becomes a BCD counter which can count in either forward or reverse directions. Its reverse direction is limited to an all 0 count which is an indication that synchronization in the receiver has been obtained.

In the "Up" condition, this subsystem becomes a BCD counter in the forward direction. This condition of operation is achieved automatically when the "Receiver" has been synchronized with the Generator.

The operation of this subsystem will be discussed in later sections of this paper.

Bit Counter Subsystem

This subsystem has one primary purpose and that is to count and display the number of bits of data that has been sent to the "Receiver" and "Exclusive OR" circuits. It consists of a seven stage BCD Counter with a "Reset to 0" and "Count Inhibit Gate". In addition, a bit select switch, search-check-lock flip-flop, errors count flip-flop, and errors count gate units are provided.

This subsystem has three conditions of operation (SEARCH, CHECK, LOCK). These conditions of operation of the bit Counter subsystem will be explained in detail in the Operational Sequence section.

OPERATION OF THE TELEMETRY TEST SYSTEM

Pseudo-Random Mode

When the "Master Reset" button is depressed; the Telemetry Test System is placed in the "SEARCH" condition. At this time, the "Generator" subsystem has a preset binary pattern inserted into its registers, and the "Receiver" subsystem has its shift registers automatically connected to the data being received from the system under test. The "Up-Down" or "Up" subsystem is automatically placed into the "Up-Down" condition and a preset error count of twenty is inserted. The "Bit-Counter" subsystem is reset to "0" and its input is inhibited.

The "Generator" will begin to output a "Pseudo-Random" code. The "Receiver" will begin to accept this data from the system under test, and "Exclusive OR" circuits will begin to indicate the comparisons.

Each comparison made is fed to the "Up-Down" or "Up" Counter subsystem. When the comparison is not in agreement, the "Up-Down" Counter counts in the forward direction. Whenever there is an agreement, the "Up-Down" Counters count in the reverse direction.

When the "Receiver" subsystem synchronizes and no errors are being generated by the system under test, the "Up-Down" Counters will immediately count down to an all "0" condition. This allows an all "0" gate within the "Up-Down" or "Up" subsystem to open, and allows the Telemetry Test System to be placed in "CHECK" operations by setting the Search-to-check "Flip-flop." This gate also inhibits the "Up-Down" Counter from receiving additional comparisons in the reverse direction and places this subsystem into the "Up" condition.

A selector switch on the "Bit Counter" subsystem has been provided to preselect the number of bits to be counted during the "CHECK" operation. When "CHECK" condition is achieved the "Bit Counter" is allowed to count the number of bits being received by the "Receiver" Shift Register. If an error is generated during the "CHECK" operation, the Telemetry Test System is automatically placed back into the "SEARCH" condition by the "Reset-to-Search Gate". The "Up-Down" counters are not preset to an error count of twenty.

If no errors are generated while the Telemetry Test System is in "CHECK", the "Bit Counter" will count to the pre-selected choice, and will immediately place the Telemetry Test System into "LOCK".

When the Telemetry Test System goes into "LOCK", the "Generator" continues to output its "Pseudo-Random" format, the receiver has the input to the

shift register removed from the incoming data train and transferred to the "Exclusive OR" circuit, the second "Exclusive OR" unit now begins to compare the incoming data to the noise-free "Pseudo-Random" source of the "Receiver" thus detecting any errors generated due to either poor signal-to-noise ratio or malfunctioning equipment, the "Up-Down" or "Up" subsystem will continue to be in the "Up" condition and will display only errors generated by the system under evaluation, and the "Bit Counter" subsystem will reset to "0" with the inputs to its counters inhibited.

Ring Mode

In the "Ring" mode the Telemetry Test System operates in the same manner as in the "Pseudo-Random" mode with two exceptions. The "Receiver" functions as a bit delay generator and the second "Exclusive OR" unit is not utilized.

SYSTEM UTILIZATION

Signal Conditioner Analysis

One important use of the Telemetry Test System is to formulate the bit error curve of a telemetry signal conditioner so that a comparison can be made with the theoretical curves drawn for these devices. The additional equipment needed to perform this test is a noise generator and a band limiting device if one is not supplied with the signal conditioner being evaluated. The following procedure is used to formulate this curve.

Set the Telemetry Test System to "Pseudo-Random" mode and run the output of the "Generator" through the noise mixing circuit. Turn the noise generator down to a minimum condition, and send the mixed data to the Band Limiter and then to the input of the Signal Conditioner. Run the output of the signal conditioner to the "Receiver" utilizing the synchronized clock output of the signal conditioner to "strobe" the "Receiver", "Up-Down" or "Up Counters", and "Bit Counters." The Telemetry Test System should immediately "LOCK". After "LOCK", simply select the proper signal/noise ratio, the proper band limiting for data rate selected and select the number of bits to be counted.

For bit error analysis, a separate button is provided on the Bit Counter subsystem which will reset the Bit Counter to 0, and allow it to count the number of bits received for comparison. The same selector switch is utilized as was used in the "CHECK" operation to select the number of bits to be counted. This switch allows a pre-select bit count from 10^1 thru 10^6 in decade steps, and in addition, has a free-run position. In this position, a pulse output is provided for

each 10^7 count of the "Bit Counter." Thus, for low error rates versus bits received, a long-term statistical measurement may be made.

The Telemetry Test System will stop after the proper bits have been counted and the errors displayed. Obtain a statistical average for each selection of signal/noise ratio and plot the several points needed for the curve and interpolate the slope. Different bit rates can be selected by simply utilizing the internal clock in the Telemetry Test System to run the "Generator".

A properly operating Signal Conditioner can now be utilized to perform additional functions with the Telemetry Test System.

Evaluation of Telemetry Ground Transmission Links

Set the Telemetry Test System to "Pseudo-Random" mode with an NRZ-C output from the "Generator." Run the output of the "Generator" to the ground transmission link and receive this "Pseudo-Random" code at the other end. Since the fundamental frequency of the NRZ-C data will vary from approximate DC to 1/2 the bit rate, and by having the capability to vary the bit rate, telemetry data can be transmitted which varies in information bandwidth from approximate DC to the upper limit of the transmission links capability. By observing the error display, an analysis of band limit capability of the telemetry transmission link can be made.

By utilizing the Telemetry Test System in the "Ring" mode, information on band limit points can be analyzed.

Evaluation of STADAN Equipment

A go-no-go condition could be easily indicated with the use of this Telemetry Test System by transmitting the telemetry from the "Generator", either directly to the pre-amplifiers in the station antenna, or to the collimation tower by RF transmission means. The data is received through the station receiving and demodulation equipment, fed into the signal conditioner, and finally to the Telemetry Test System where a bit error analysis is made.

STADAN Fly-By Performance Evaluation

The Operation Evaluation Branch is utilizing the Telemetry Test System to conduct fly-by tests at STADAN sites. The procedure for using the telemetry test system in these fly-by tests follows.

A "Pseudo-Random" Generator is placed aboard the calibration aircraft and the data format selected is fed to the modulator of our telemetry transmitters. The RF signal is tracked and received by the station's antenna and sent through the receiving and demodulation systems in the same manner as a satellite pass would be handled. The output of the signal conditioner is fed to the Telemetry Test System. After "LOCK", the output of the "Generator" in the aircraft is attenuated simulating different satellite ranges. The errors generated under these conditions along with other forms of test information indicates a station's ability to properly track and handle satellite data.

TELEMETRY TEST SYSTEM RELIABILITY

This Telemetry Test System has been checked under the following conditions with no internal errors being generated. It was operated for a period of eight hours at a bit rate of 100 cps, and with an under-voltage condition of thirty percent under room temperature conditions. No errors were generated internally during this test.

The same test was performed at a bit rate of 2 megacycles. No errors were generated internally after 576 X 10^8 bits were passed through the system.

Further tests have been performed utilizing a separate "Pseudo-Random" generator transmitter and receiver with no internal errors generated under thirty percent undervoltage conditions for a period of 1 hour, at bit rates from 100 cycles to 2 megacycles in 10 kc steps.

Fly-by tests have been performed at altitudes up to 18,000 feet utilizing this system and satisfactory results were obtained.

CONCLUSION

This report has shown several different applications for this Telemetry Test System. We believe that additional usages can be made with slight adaptation. A very simple and rapid method of determining errors vs bits transmitted has been demonstrated. It is believed that this system offers a very unique aid in evaluating station telemetry equipment.

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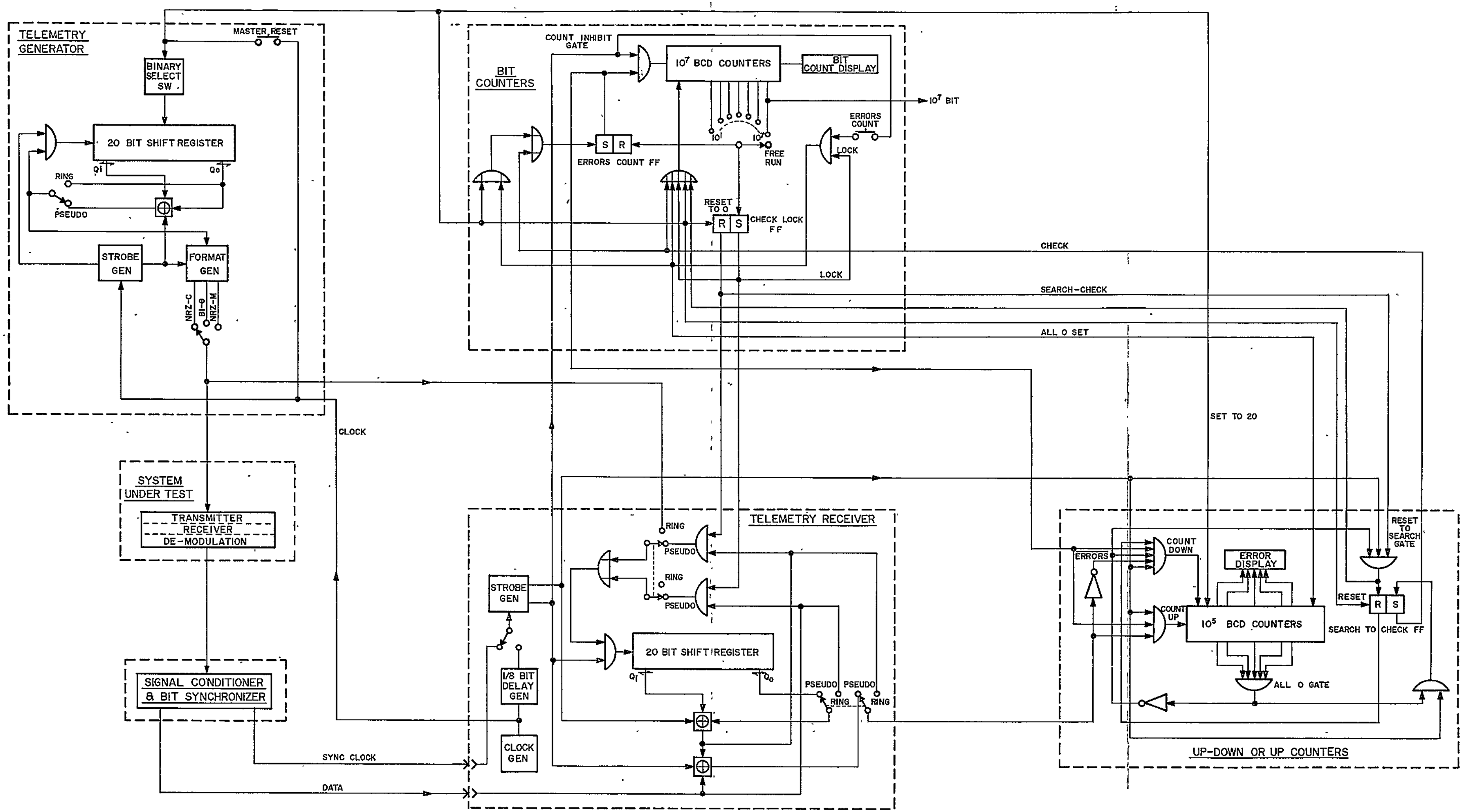

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A prototype Telemetry Test System designed to meet the need for rapid checkout techniques to insure the functional operability of the STADAN telemetry system at any given time is described The system consists of four subsystems (generator telemetry receiver, up-down or upcounter, and bit counter) each of which is designed to operate under two general modes, ring or pseudorandom The use of the system to formulate the bit error curve of a telemetry signal conditioner to evaluate telemetry ground transmission links and STADAN equipment and to conduct flyby tests at STADAN sites is exemplified S C W.

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